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THESIS

SPATIAL ORIENTATION AND FAMILIARITY IN A SMALL-SCALE REAL ENVIRONMENT USING PC-BASED VIRTUAL ENVIRONMENT TECHNOLOGY

by

Matthew Molmer

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Thesis Advisor:	Rudy Darken
Co-Advisor:	Perry McDowell

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13. ABSTRACT (maximum 200 words) Conducting training in a new or unfamiliar environment requires a certain amount of time to acquire the necessary spatial orientation and familiarity to that environment's physical layout. This thesis explores the effects of exposing individuals to a PC-based virtual replication of a small-scale real world training environment to determine if such exposure has any effect on an individual's ability to acquire the necessary spatial orientation and familiarity of the real world environment. In this thesis individual spatial orientation and familiarity to the layout of the real world environment will be measured using a set of retrieval tasks conducted in the real environment and by development of a sketched map of that environment. Establishing a link between an individual's ability to gain an acceptable level of spatial orientation and familiarity with a real world environment by first exposing them to a PC-based virtual replication of that environment is vital to the future of video game development and virtual simulation technologies used for training in the military.

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SPATIAL ORIENTATION AND FAMILIARITY IN A SMALL-SCALE REAL ENVIRONMENT USING PC-BASED VIRTUAL ENVIRONMENT TECHNOLOGY

Matthew NMN Molmer
Lieutenant, United States Navy Reserve
B.A., Georgia State University, 1999

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Author: Matthew Molmer

Approved by: Rudy Darken,
Thesis Advisor

Perry McDowell
Co-Advisor

Rudy Darken
Chair, MOVES Academic Committee

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ABSTRACT

Conducting training in a new or unfamiliar environment requires a certain amount of time to acquire the necessary spatial orientation and familiarity to that environment's physical layout. This thesis explores the effects of exposing individuals to a PC-based virtual replication of a small-scale real world training environment to determine if such exposure has any effect on an individual's ability to acquire the necessary spatial orientation and familiarity of the real world environment. In this thesis individual spatial orientation and familiarity to the layout of the real world environment will be measured using a set of retrieval tasks conducted in the real environment and by development of a sketched map of that environment. Establishing a link between an individual's ability to gain an acceptable level of spatial orientation and familiarity with a real world environment by first exposing them to a PC-based virtual replication of that environment is vital to the future of video game development and virtual simulation technologies used for training in the military.

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I. INTRODUCTION

A. PROBLEM STATEMENT

The focus of this research is to explore and measure, using a PC-based virtual environment, participants' level of spatial orientation and familiarity to a new real world environment by allowing them to perform a set of specific tasks within that real world environment. If data reveals there is a correlation between pre-exposure to a real world environment, it may be possible to use a PC-based virtual replication of that environment to acquire a level of spatial orientation and familiarity with that environment adequate enough to conduct an evaluated task. If so, using such a virtual environment may reduce the time in the actual location to raise a service member's knowledge of that location to a required level. In addition, future video game-based simulators and trainers could develop environments with the knowledge that not only are they able to train a specific set of skills, but also the environment in which the game is scoped. The focus of this research is to explore and measure, using a PC-based virtual environment, the effectiveness of acquiring a adequate level of spatial orientation and familiarity to a new real world environment by allowing participants to perform a set of specific tasks within that real world environment. If data reveals there is a correlation between pre-exposure to a real world environment, using a PC-based virtual replication of that environment, and acquisition of a level of spatial orientation and familiarity with that environment adequate enough to conduct evaluated performance task, viable man hours used to get a service member up to speed on an environment's physical layout could be greatly reduced. In addition, future video game-based simulators and trainers could develop environments with the knowledge that not only are they able to train a specific set of skills, but also the environment in which the game is scoped.

B. RESEARCH QUESTION

Can pre-exposure to a PC-based virtual replication or model of an actual training environment provide participants with an adequate level of spatial knowledge to perform similarly on specific task as participants who were pre-exposed to the real world training environment?

C. DISCUSSION AND MOTIVATION

The most effective method of becoming spatial orientated or familiar with the layout of a new or unfamiliar environment is to physically step foot into that environment, touch the walls, smell the air, and listen to the sounds that may or may not be there. However, this is often impractical or impossible, especially in the military context. Unfortunately, this often has significant consequences for the military.

Consider, for example, a newly enlisted Sailor who reports to his first shipboard tour. To say that this environment is new and unfamiliar is a dramatic understatement. It will take this Sailor several days, if not weeks, to properly acclimate him to the physical layout of the new shipboard environment. During this time, the sailor is of little use as a member of the crew. Now give that same Sailor a technology that pre-exposes him to the physical layout of the interior shipboard environment; in this case, a PC-based virtual replication or model of the interior spaces onboard the ship before he ever arrives for duty. Using this virtual model of the ship, he is able to explore the many spaces within the interior confines in the hull of the ship. Upon completion of his exposure to the shipboard environment in the virtual model and finally reporting aboard, he is already days or even weeks ahead of what he might have been, in terms of spatial familiarity, with out the pre-exposure to the virtual shipboard environment. The time it will take for the Sailor to properly acclimate to the new environment is significantly reduced and the Sailor more quickly becomes a critical member of the ship's crew and emergency teams.

The previous scenario serves to illustrate a need for providing a safe and inexpensive way for not only Sailors, but all who report to a new or unfamiliar environment and are expected to perform some type of task requiring spatial knowledge of that environment. Whether the task is conducting training, emergency response, search and rescue, or even normal day to day operations, a basic level of spatial orientation and familiarity may be greatly enhanced from pre-exposure to that environment leveraging PC-based virtual environment technologies. In Addition the use of a PC-based virtual replication of a real world environment may also be ideal for refreshing an individual's spatial orientation or familiarity to an environment that they may have been removed from for some period of time or have only seen a few times before.

The motivation for this thesis is in determining if pre-exposure to a PC-based virtual environment affects an individual's ability to acquire a similar, if not higher, level of spatial orientation and familiarity than an individual pre-exposed to the real world environment. Toward that end, the findings from this study will set a benchmark for future PC-based video gamed trainers and simulators in the military in which knowledge of a specific environment's physical layout is essential for successful task completion.

If results indicate that pre-exposure to a PC-based virtual replication of a real world small-scale environment reduces the time for an individual to a complete task (i.e. find one's way around the environment quicker) or at least be familiar enough with the physical layout of the real environment to produce an adequate sketch of that environment, time spent on acclimating military personnel to the spatial aspects of a new space may be effectively reduced.

The target population for the experiment covers a wide range of domains, from the Army's dismounted infantry Soldier preparing to enter an unfamiliar building on a search and rescue mission, to the Navy's newest Sailor reporting aboard his tour aboard a ship. If PC-based virtual environments were available and proved to be successful in training spatial orientation and familiarity, man hours and elaborate simulation cost could be significantly reduced.

1. Relevance of Research

The relevance of this research will be to provide basic criteria for the US Navy and, in general, the Department of Defense to develop PC-based virtual gaming technologies that can provide an individual with a requisite level of spatial knowledge to a real world environmental. The need for a particular military unit to become acclimated to a new environment's physical layout before ever arriving at that environment is essential. Reducing the training time to properly acclimate a trainee to a new training environment, allowing more time to be spent on specific skill sets necessary for task accomplishment, is also a relevant focus of this research. The Navy could expose shipboard firefighters and emergency response teams to an inexpensive PC-based virtual replication of a shipboard environment to facilitate training in the real world environment. Army dismounted infantry Soldiers could explore a virtual replication of a

building before storming the actual building, knowing that once inside, their level of spatial orientation and familiarity with the interior layout of that building will enhance their ability to complete their mission.

D. THESIS ORGANIZATION

The focal point of this thesis will be to conduct a research experiment focusing on using a PC-based virtual representation of an actual US Navy real-world training environment to pre-expose participants to the physical layout of the actual training facility. After a predetermined time of exposure to the virtual training environment, participants will complete selected performance measures to qualify their performance in the real world environment. The performance measures of each participant exposed to the PC-based virtual environment will be compared to participants who were pre-exposed to the real training environment. The experiment involves using two randomly selected groups of U.S. Navy enlisted personnel with no prior knowledge of the actual training environment. The control group will be pre-exposed to the actual training environment and the experimental group will be pre-exposed to the training environment using a PC-based virtual representation of the environment. This research will serve as benchmark for future guidance on developing and implementing PC-based virtual environments into game-based training systems to meet military training requirements.

II. BACKGROUND

The ability for an individual to acclimate himself to the interior physical layout of a real world environment is essential in order to successfully complete a task or mission in the military. From shipboard Navy firefighters, to dismounted infantry Soldiers, acquiring the necessary spatial orientation and familiarity of the physical layout of a new or unfamiliar environment can mean the difference between life and death. The most efficient way to learn the physical layout and spatially acclimate someone to a new or unfamiliar environment is by actually immersing that person in that real world environment. However, with many military applications, that maybe impractical, expensive, or in some case dangerous. When the location is unavailable, other methods have been used to replace the real location, such as mock-ups, maps, models or even pictures of the actual environment. Again, this approach may prove to be impractical and/or expensive to conduct in some cases. Additionally, this requires effort that could be better focused on other aspects of mission accomplishment.

With the advent of technological improvements over the last decade in computer graphics, processor speed, and enriched display devices; virtual environment (VE) technology has proliferated to a point of greatly enhancing training for individuals as well as teams. For example, the use of virtual environments in shipboard firefighting has become a top consideration in US Navy with respect to how best to train firefighters. While training firefighting skills have been the main focus for using virtual environments, the ability for a firefighter to acquire a requisite level of spatial orientation and familiarity of an impending real world environment is as important. He will be expected to successfully navigate through the many spaces of the environment in order too extinguish a fire or rescue a fallen crew member. This expectation is a paramount consideration when developing virtual environments trainers and simulators.

Although there are many variables to consider when developing a VE in order for it to be an effective training tool, the concept of spatial knowledge acquisition and its effects on navigation is perhaps of the most important. If a VE environment does not afford the spatial knowledge or environment familiarity for a user to successfully

navigate through the real world environment, then training of the kind mentioned above can not take place. According to Darken et al, it has often been suggested that due to its inherent spatial nature, a VE might be a powerful tool for spatial knowledge acquisition of the real environment, as opposed to the use of maps or some other two-dimensional, symbolic medium (1998).

One of the first studies to show that a virtual environment could be useful for spatial knowledge acquisition, Witmer et al (1995) compared a virtual environment to the real world in an architectural walkthrough application. Their participants were not experts on the task domain and used an immersive head-mounted display system which employed gazed-directed movement control.

The experiment was divided into four phases: Phase one, individual assessment, involved self-reporting questionnaires which centered on participant's perceived sense of direction and navigation experience. In phase two, study, each participant was given fifteen minutes to study written step-by-step route directions and color photographs of landmarks. Some of the participants were also given a third study aid, which consisted of a map of the real environment. In phase three, rehearsal, each of the participants was given an opportunity to rehearse their route in either the real or virtual environment, depending on the group they were assigned to. Each participant had to identify six landmarks on the route. Any wrong turns and misidentified landmarks made by a participant were immediately corrected for by the researchers. In the final phase, testing, participants replicated the route they had rehearsed and asked to identify the six landmarks they had studied in the real building environment. Replication of the route in the real building was measured as attempted wrong turns, time to traverse route, distance to traverse route, and number of misidentified landmarks. Participants were also asked to draw a line on a map from their known location to an unseen target to test their knowledge of the configuration.

This study showed that route knowledge could be effectively trained to some degree using virtual environment technology. Exposure time to the VE was limited however, which reduced the effects that it may have had on developing survey knowledge.

Along the same lines, Darken and Banker (1998) used a VE to study how it might be used in addition to traditional real environment familiarization methods. In their research, they looked at three different groups: The first group was restricted to only using a map, the second group used a VE in conjunction with a map, and the third group was restricted to using only the real environment augmented with a map. Participants interacted with the environment through a keyboard and conventional desktop display. Participants in this study were experts on the task domain and the environment involved a large nature region of central California.

The experiment consisted of two phases. In phase one, planning and rehearsal, participants studied and plan a route from a starting point through nine successive control points, culminating with each participant having to draw their planned route on a map. In the next phase, testing, participants executed their planned route without the assistance of the map or a compass. The performance measures were quantity of unplanned deviations from their planned route and total distance traveled.

This study differs from Witmer et al's earlier study in that the participants planned and practiced their own route, not a route that was given. Additionally, the participants were experts on the task domain and the time of exposure to the VE was four times longer.

The results of this study showed that beginners to the task domain were not assisted by the VE exposure; intermediate users benefited the most from the VE exposure; advanced users did not show any improvement. To explain this, Darken and Banker point out that beginners lack the level of knowledge on the task domain to be assisted by the VE; advanced users are so experienced in the task domain that the VE did little to improve their performance. They concluded that given a short train-up time, maps still seem to be the best alternative to spatial knowledge acquisition.

In a study conducted by Koh et al (2000), development of configurational knowledge using an architectural environment was investigated. In the study, the researchers compared four different groups. The first group was the real world group, the second group used an immersive VE, consisting of a head mounted display (HMD), the third group used a desktop VE, consisting of a typical computer monitor, and the fourth group used a hand held World-In-Miniature device. Each of the participants was

randomly assigned to each of the four groups and there were no expert knowledge on the task domain. The users of the two VE groups controlled their motion speed and direction through the use of a joystick.

The actual experiment was executed in three phases. The administration phase consisted of informing the participants of the task that would be completed, but specific target information was not disclosed. During this first phase, participants using the VEs were also allowed time to become familiar with their respective interfaces. In the next phase, training, participants were given ten minutes to explore either the VE or the real environment depending on the group they were assigned for the experiment. In the final testing phase of the experiment, participant's configurational knowledge was tested by asking them for bearing and distance estimations to unseen targets. The results of this study showed that configurational knowledge could be just as effectively training in a VE as in a real world environment.

In 1998, Waller et al conducted a study which used six different type of treatment condition to further answer questions about VE ability to acquire spatial knowledge. The treatment groups were divided into a real world group, a group that had no-study, and three VE groups (desktop, short-duration immersion, and long-duration immersion). The participants in the study were non-experts on the task domain and the environment used in the experiment was a maze with targets placed a specific locations. Each of the VE groups used a joystick for motion control in their respective environment and the immersive groups used a HMD. The short-duration immersive group was allowed twelve minutes to practice in the VE and the long-duration group was allowed thirty minutes of practice time.

The experiment was executed in four phases. In the first phase, the participants were administered a Guiford-Zimmerman spatial abilities test. The second phase consisted of allowing the participants to interweave practice and testing in the environments for a total of six runs. In the third phase, the researchers altered the maze configuration so that portions of the learning maze were blocked and the participants had to find a new route to traverse, this tested their survey knowledge. Performance measures for the previous two phase included time to traverse a route and number of times a participant bumped into a wall. In the final phase participants complete a configurational

knowledge test of the maze environment. This study gave credence to and showed that given enough exposure time, training in a VE could be more effective in training spatial knowledge then the real world environment.

Although all of the previous research have shown that training in a VE can be as effective as training in a real environment, these studies are of a general nature and may not transfer to a specific task domains. Research needs to be completed on specific task domains in order to investigate feasibility of training that problem domain in a VE.

Accordingly, in the task domain of shipboard firefighting the research is limited with only two such studies completed to date. The first such study conducted by Bliss et al (1995) showed that fire fighters exposed to a virtual environment of an office building improved their navigational abilities through the building when conducting search and rescue operations.

The other such study specifically tied to training spatial knowledge in firefighters was conducted by Tate, Sibert, and King (1997). In their study the researchers explored the feasibility of using immersive VE technology as a tool for shipboard firefighting training and mission rehearsal. The researchers modeled portions of the Navy's ex-USS SHADWELL (LSD-15), a former amphibious ship now used as a firefighting lab in a VE. The system employed an immersive, head-mounted design (HMD) device to view the virtual 3D model of the environment and a 3D joystick for motion control and interacting with the virtual environment. The participants in the study were divided into two groups, a traditional and a VE group; the participants were experts on the task and none were familiar with the real environment.

The study was divided into two phases. Phase one consisted of a navigational task that did not involve firefighting skills. The task was to traverse a specified path through a simulated smoke filled ship environment. Performance measures included time to traverse the route and number of wrong turns taken. In the second phase, participants were required to retrieve specific gear, perform standard firefighting procedures, and lead the firefighting team to extinguish an actual shipboard fire. The purpose of this phase was designed to evaluate whether or not a VE helps fire fighters actually extinguish a fire faster than firefighters without VE training.

The results from this study showed that there was a measurable improvement in the performance of firefighters that used VE for mission rehearsal over firefighters without VE in both phases of the test. Additionally, the study showed that VE's can be effectively used for training shipboard familiarity as well. Further, Tate et al sighted that VE's provide a flexible environment where a firefighter can not only learn an unfamiliar part of the ship, but also practice tactics and procedures for fighting a live fire.

This and other previous studies in the area of training using virtual environments have proved to be a monumental step in showing how such technology could be successfully employed to train shipboard firefighting and other general task accomplishments, more importantly however, spatial knowledge acquisition of unfamiliar environments. However, these studies were based on training employing the concept of immersive type of technology, such as HMDs or CAVEs. Toward this end, additional research needs to be conducted on training firefighters and other task domains leveraging VE technologies designed around typical display devices, allowing interaction between individual and the VE through traditional methods (i.e. standard keyboard & mouse devices). Measuring the effects that this might have on spatial knowledge acquisition is of great importance as well.

III. METHODOLOGY

A. EXPERIMENT OVERVIEW

The goal of this experiment was to determine if using a PC-based virtual replication or model of a real world small-scale environment had a positive affect on an individual’s ability to acquire a sufficient level of spatial orientation and familiarity with the physical layout of the real world environment in order to successfully perform a set of performance measures in the real environment. The following section describes in more detail the phases and procedures used to conduct the experiment.

The experiment was conducted in San Diego, CA at the US Navy’s Damage Control and Fire Fighting School. The venue was the F-1 Fire Fighting Training (see Figure 1). Participants were Sailors currently assigned to the Navy Pre-Commissioning Detachment (PCD) and were randomly selected to participate in the experiment. All participants were briefed on the experiment and completed the required consent form. (See Appendix A and B). Participants were also given a brief survey to gather key demographic information and general work experience. (See Appendix E).

Figure 1. F-1 Fire Fighting Trainer, San Diego, CA

Participants were randomly divided into two separate groups for the entire experiment: a real environment group and a virtual environment group. Each group explored the spaces within their respective environments. Upon completion of the environment exploration, each participant reconstructed from memory a detailed map of the environment in which they explored. Each participant then performed a set of retrieval tasks within the real environment. Participants were asked to retrieve a certain colored flag in a particular space located on a specific piece of equipment within the real world environment.

The first test was scored based on the correct number of rooms sketched and the correct location of equipment inside each of the rooms. The retrieval tests were scored using the time to successfully retrieve the correct colored flag.

Upon completion of the experiment, each participant was debriefed and thanked for their participation in the experiment.

B. EXPERIMENTAL DESIGN

The experiment conducted was a 'between subjects' design. The virtual environment group was pre-exposed to the virtual replication of the real world environment before conducting their tests in the real environment. The real environment group was pre-exposed to the real environment before conducting their test in that same environment.

1. Participants

There participants for the experiment consisted of 14 US Navy active duty enlisted sailors. They ranged in pay grade from E2 to E6. The age range was 18 to 29 years with an average age of 23. The participants all had varying degrees of experience in a shipboard environment with an average time in service at 3.5 years. Gender was not a consideration in the study due to the fact that only one of the fourteen participants was female. Of the participants, 43% of them were in non-technical ratings or jobs. None of the subjects had prior knowledge as too the physical layout of the F-1 Fire Fighting Trainer.

2. Environment Exposure

Each group was systematically exposed to their respective environments before any testing occurred in the real world environment. The virtual environment group was given a short training session on how to maneuver within the virtual model located on the PC. After completion of the training session, participants explored each room within the model. Time within each space was limited to five minutes. Within each room participants we given a guided tour (see Appendix C). Their attention was drawn to specific aspects within each space, including the location of specific pieces of equipment. The real environment group was given exactly the same guided tour during their exploration of the real world environment. The time spend in each space was consistent with the time for the virtual environment group.

3. Order of Test

Upon completion of the exploration phase of the experiment, each participant completed a detailed sketch of the environment in which they toured. This test was completed prior to conducting the retrieval tasks to avoid any learning effects after exposure to the real environment during the second phase of testing. The measure used to quantify the performance of each group was a combined score based on the number of rooms draw and the correct placement of equipment within a particular space. Sketches were drawn on a ‘spatial exam’ form designed specifically for the experiment, which is provided in Appendix B. It is important to note that artistry and scale were not considered when scoring the exam. Only placement of rooms and equipment was considered in the scoring process. Figure 2 shows a ‘ground truth’ depiction of the real world environment and was used to score the participant’s sketches.

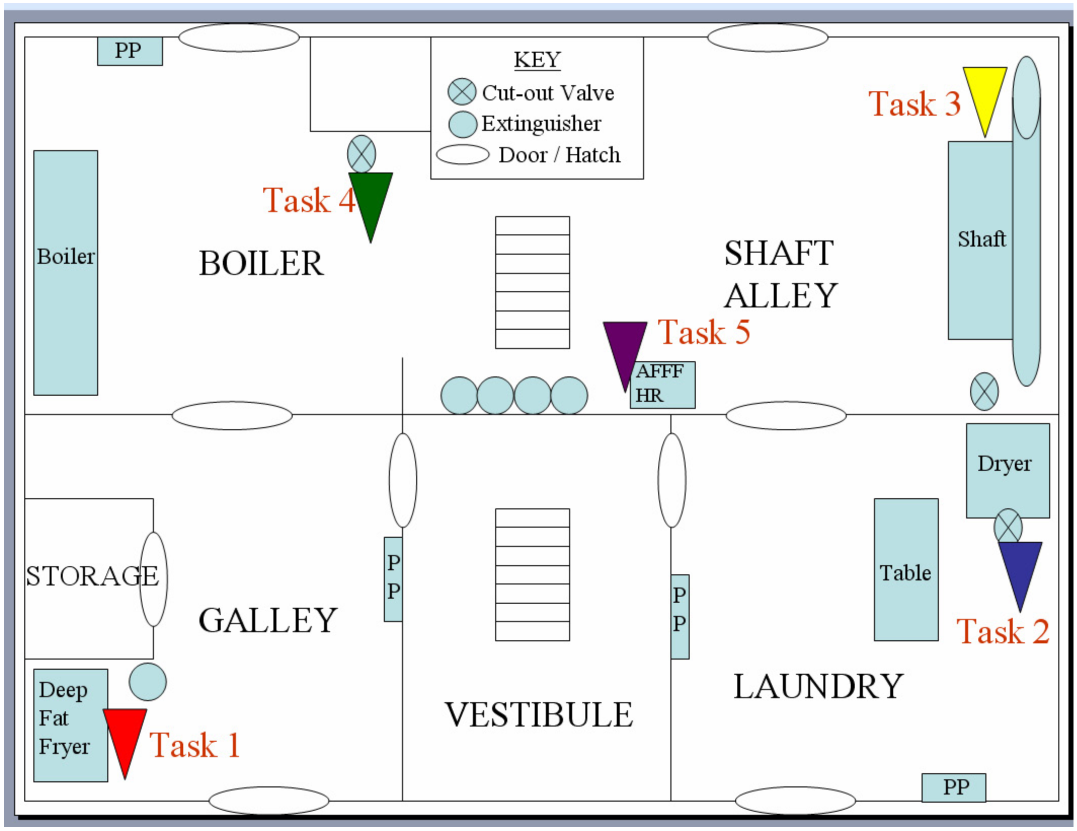

Figure 2. Ground Truth Layout and Flag Placement

The second tests consist of randomly assigning each participant two separate, but equivalent, retrieval tasks. In each task participants had to retrieve a specific colored flag located within one of the spaces in the real world environment. Figure 2 also shows the location and color of each of the flags and their location used for the second test. The measure used to quantify the performance of each participant was the time to retrieve the assigned flag.

C. VENUE

1. Real World Environment

The environment selected to conduct the experiment was the US Navy's F-1 Fire Fighting Trainer, located in San Diego, CA. (see Figure 1). The selection of this venue was two-fold. Firstly, it represented a typical shipboard environment in which US Navy personnel would be expected to be familiar with in order to effectively conduct training.

Secondly, once modeled in a virtual environment for this experiment, it could be expanded for future studies of this kind.

2. Virtual Environment

The virtual environment was an exact 3D graphical representation of the F-1 Fire Fighting Trainer. The model was created using 3D Studio Max by Matt Prichard, a modeler and artist at the Naval Postgraduate School (NPS). The motion model was designed by Eric Johnson and Perry McDowell also at NPS. The virtual model was validated by the Officer in Charge and the staff instructors at the Damage Control and Fire Fighting School in San Diego, CA. Figure 3 shows the first level of the virtual F-1 Fire Fighting Trainer model.

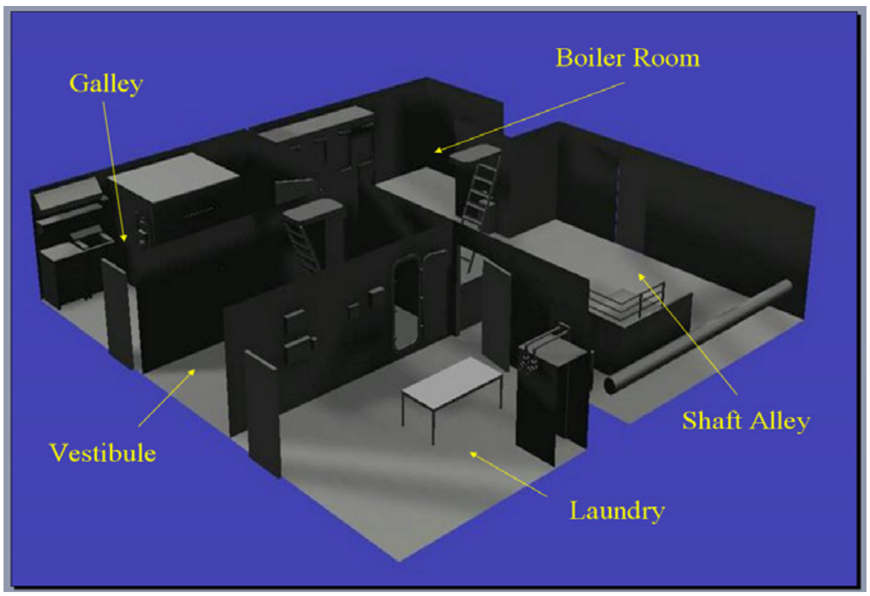

Figure 3. First Level of Virtual F-1 Trainer Model

Figure 4 below compares the deep-fat fryer room in the real environment (left) and in the virtual environment (right).

The model was run on a standard desktop computer with a Pentium 4 processor and 512 Mbytes of RAM. The interface was a standard keyboard and mouse. Participants interacted with the virtual model through mouse and keyboard. The mouse was used for lateral motion and for looking up and down. Keyboard keys ‘w’, ‘s’, ‘a’, and ‘d’, were used to step forward, backward, left, or right, respectively, the standard PC first person

shooter motion model. Motion through the virtual environment was held at a speed equivalent to the walking pace of the real environment group.

The display used in the experiment was a standard 17 inch LCD flat-panel. The configuration of hardware was chosen based on standard equipment readily available to most Navy personnel in the fleet. The idea was not to introduce any new hardware configurations that were not in common use.

Figure 4. Real vs. Virtual Environment

D. MEASUREMENT SELECTION

The performance measures selected for the experiment were based on a detailed review of the literature with respect to completion of task in virtual and real environments. Based on the literature reviewed there are three main components that makeup spatial knowledge and would be measured in the experiment: Landmark; Route; and Survey (Karahan 2000).

Although the efficacy of each component, according to Karahan, can be evaluated using several different performance measures the following were selected for the experiment.

1. Sketch Mapping and Map Placement

In order to measure a participant's familiarity, or survey knowledge, of the real environment after being exposed first to a virtual replication of that environment, a combination of sketch mapping and map placement were used in the experiment. These performance measures were selected in order to quantify the mental or cognitive map that participants developed of the real environment after first being exposed to either a virtual replication of the environment or the actual environment itself. Although there are some who feel that the use of such a performance measure is problematic since they are difficult to score and may under estimate the actual knowledge acquired (Siegel 1981), the experiment revealed that by combining the sketch mapping and map placement tasks and scoping it within the context of an environment without a high level of detail, it is quite useful in gauging a participant's familiarity or survey knowledge of the environment's physical layout.

2. Retrieval Task

To measure a participant's landmark and route knowledge, the choice was made to combine both measures into evaluating the time to retrieve a certain colored flag in a specific location within the real environment. Although Karahan's work on performance measures in virtual and real world environments briefly addresses a walking task as not a viable measure to quantify performance, the retrieval task used in the experiment proved to be a viable measure to quantify a participant's performance in a real or virtual environment.

Based upon previous research and in this experiment, there is evidence that the retrieval task can incorporate the many of the measures Karahan points to in order to measure landmark and route knowledge. In order to retrieve an object from a specific location within an environment, the participant must be able to apply the necessary landmark and route knowledge of the environment to successfully navigate though the environment, obtain the object and return with it. If that is not the case, the participant is

considered lost and his time to retrieve the object will reflect that. In this experiment, one participant became lost or disoriented within the environment and the time to retrieve his object was much greater than the other participants in his group.

IV. ANALYSIS

A. RESULTS

1. General Information

The experiment is designed to test a hypothesis concerning the correction between spatial orientation and familiarity with the layout of a real world environment after pre-exposure to a PC-based virtual replication or model of that environment. To determine quantify participant performance, their times to search for and retrieve two separately located flags in the real environment and a combined score assessing their ability to reconstruct the layout of the real environment using a sketch were used.

a. Hypothesis

Participants exposed to a 3D virtual replication of a real world environment will have the same spatial orientation and familiarity as participants pre-exposed only to the real world environment.

1. A participant who has gained a level of familiarity with the real environment will be able to reconstruct the physical layout of that environment in the form of a sketch.

2. A participant who has gained a level of spatial orientation will be able to search for and retrieve a specified flag located in one of the real environment spaces in a time equivalent between groups.

2. Significance Level

The experiment involved a relatively small sample size; however, to keep consist with previous studies involving human participants and virtual environments an α value of .05 was used for all analysis to determine statistical significance between the virtual and real environment groups.

There were five different search and retrieve tasks in the second testing phase of the experiment. Participants were randomly assigned to complete two of the five tasks. The assumption was made that there was no difference between the five task based on

results of an ANOVA using the independent task to determine main effects. This assumption is an important first step in the overall analysis in order look at only the significance between groups.

The data in the succeeding section is presented using box plots, scatter plots, and frequency plots.

3. Spatial Exam Results

To compare participant's acquisition of survey knowledge between groups, each participant was instructed to sketch a map of the environment in which they were exposed to during the guided tour phase of the experiment. In addition, participants were also instructed to place specific items that they viewed in the environment in the correct location on their map.

The box plot in Figure 5 displays the spatial exam scores for each of the two groups. The mean score for the real group was greater ($M=20.29$, $s=1.604$) than the mean score for the virtual group ($M=10.33$, $s=3.077$). A summary of these results is presented in Table 1. An independent sample test indicated that there was a statistical significance between the groups' ability to recall and reconstruct the spatial layout of the real environment, $t(11)=7.489$, $p=.00$.

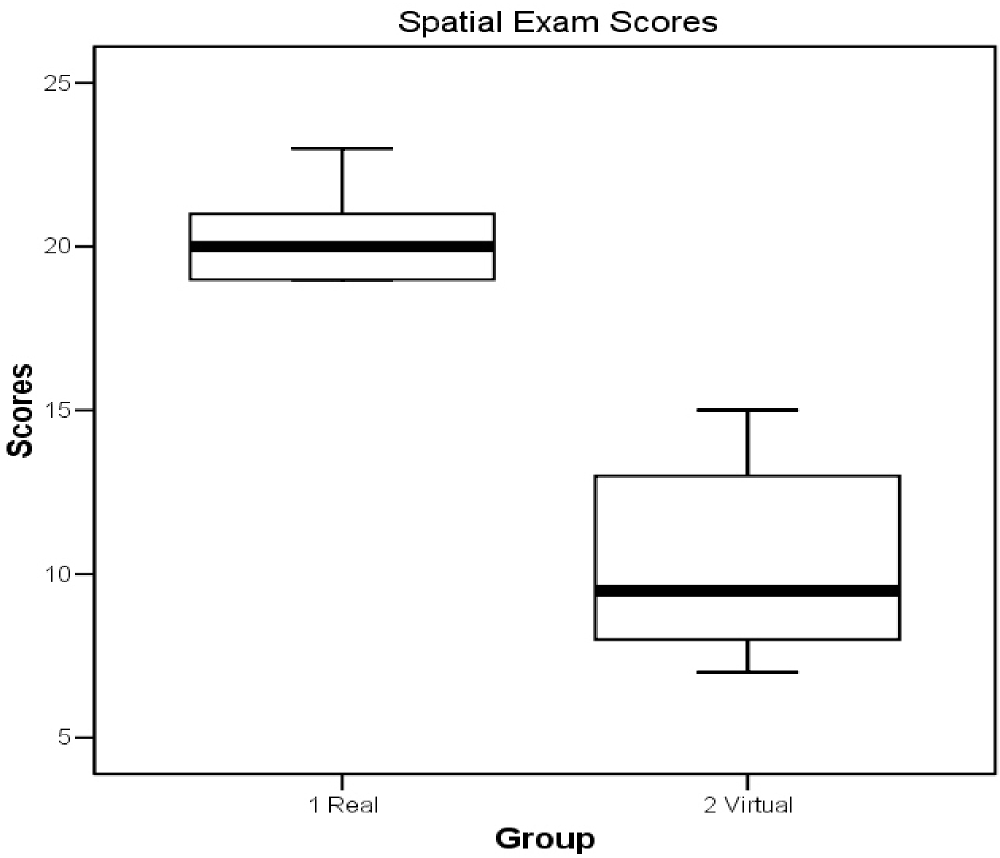

Figure 5. Spatial Exam Scores for Each Group

Group	N	Mean	Std. Deviation
1 – Real	7	20.29	1.604
2 – Virtual	7	10.33	3.077

Table 1. Summary Statistics for Spatial Exam Scores

4. Retrieval Tasks Results

To compare acquired landmark and route knowledge between the real and virtual environment groups a set of retrieval task were performed in the real environment. The bar chart in Figure 6 graphically displays each participant's time to accomplish both task one and task two. The real environment group on the graph are numbered one to seven, with participants in group two, the virtual environment group, numbered eight through fourteen. From the graph, a general observation of the data indicates that overall,

participants in the real environment group appear to have performed better, having a shorter time on task one then group two. On the other hand, both groups appear to have performed at or near the same level during performance of task 2.

During the initial stages of data analysis, participant eleven in group two was determined to be an excessive outlier. Closer examination of participant eleven revealed that he was not indicative of the target population for this study; therefore participant eleven's data was extracted from the remaining data analysis.

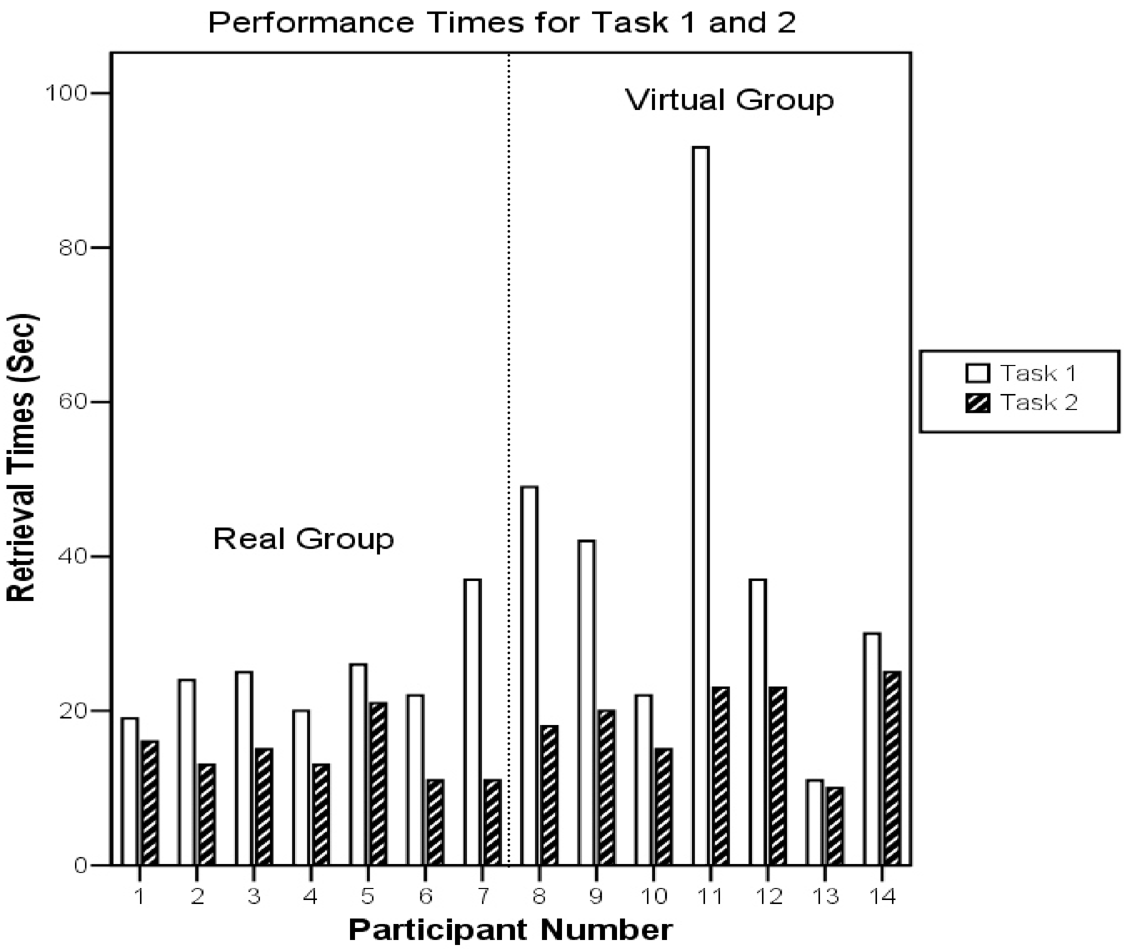

Figure 6. Task One and Two Retrieval Times for Each Participant

The group times to successfully retrieve the first flag are displayed in a box plot in Figure 7. The mean time for the real group was less (M=24.71, s=5.992) than mean time for the virtual group (M=31.83, s=13.848). A summary of these results is presented

in Table 2 below. An independent sample test indicated that there was not a statistically significance difference between the group's ability to formulate the required spatial orientation or knowledge of the real environment in order to successfully retrieve their first flag, t(11)=-1.238, p=.241.

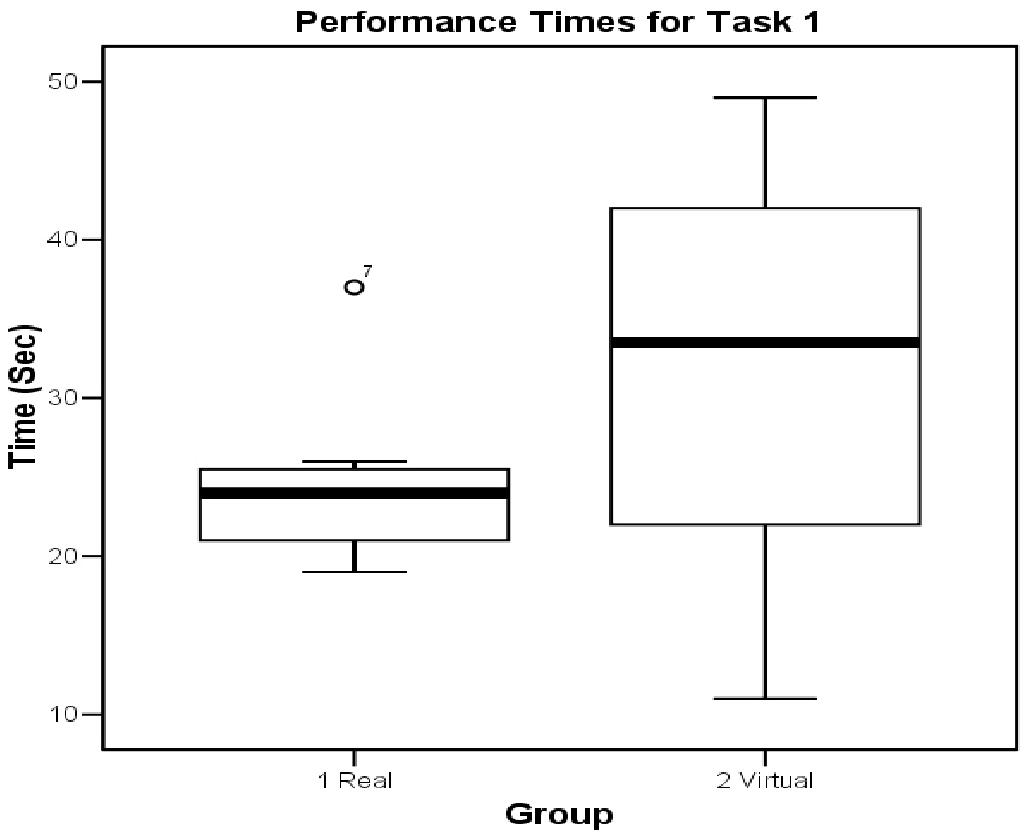

Figure 7. Time to Retrieve First Flag

Group	N	Mean	Std. Deviation
1 – Real	7	24.71	5.992
2 – Virtual	6	31.83	13.848

Table 2. Summary Statistics for Task 1

The group times to successfully retrieve the second flag are displayed in a box plot in Figure 8. The mean time for the real group was less (M=14.29, s=5.992) than

mean time for the virtual group (M=18.50, s=5.468). A summary of these results is presented in Table 3 below. An independent sample test indicated that there was not a statistical significance between the group's ability to formulate the required spatial orientation or knowledge of the real environment in order to successfully retrieve their second flag, t(11)=-1.683, p=.121.

These results indicate that after each group was exposed to the real environment during task one, participants in each group performed better overall. However, one group did not do significantly better than the other group.

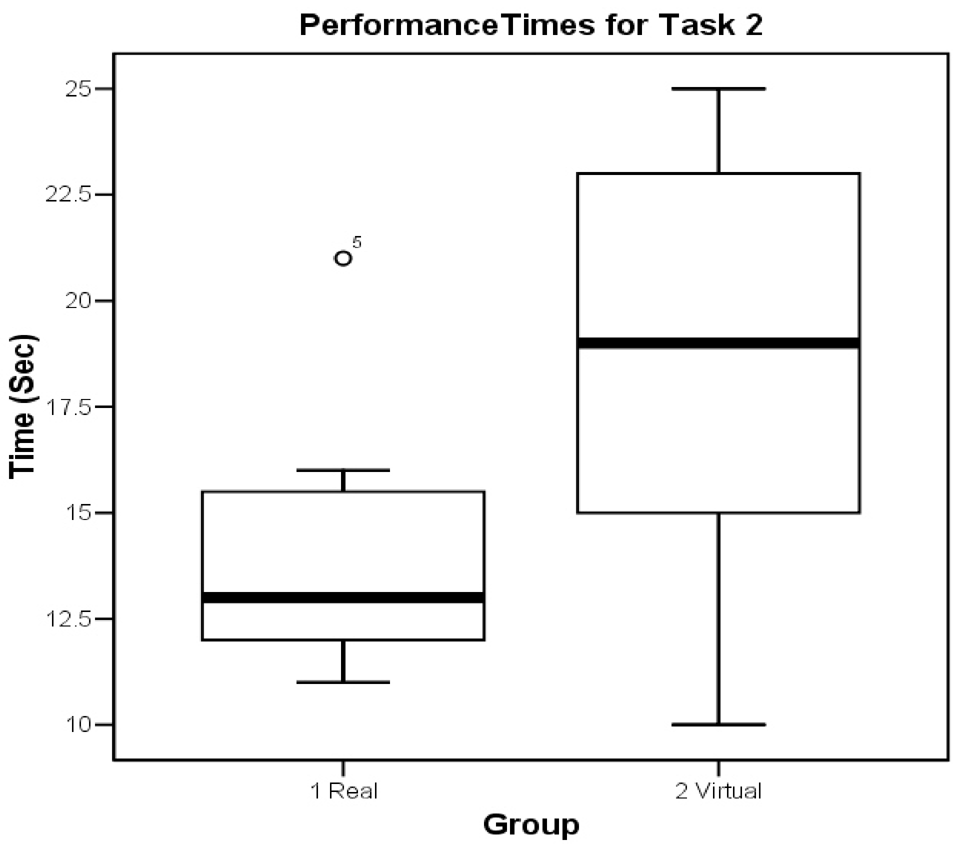

Figure 8. Time to Retrieve Second Flag

Group	N	Mean	Std. Deviation
1 – Real	7	14.29	3.498
2 – Virtual	6	18.50	5.468

Table 3. Summary Statistics for Task 2

Looking at the relationship displayed in a scatter plot graph, Figure 9, between exam scores and retrieval times for group 1, there was not a relationship ($r=-.099$, $p>.05$). However, looking at the relationship between group exam scores and retrieval tests for group two, there was a strong negative correlation between exam scores and retrieval times ($r=-.829$, $p=.042$). These results indicate that participants in group two who performed lower on the spatial exam had a more difficult time finding their flags in the real environment.

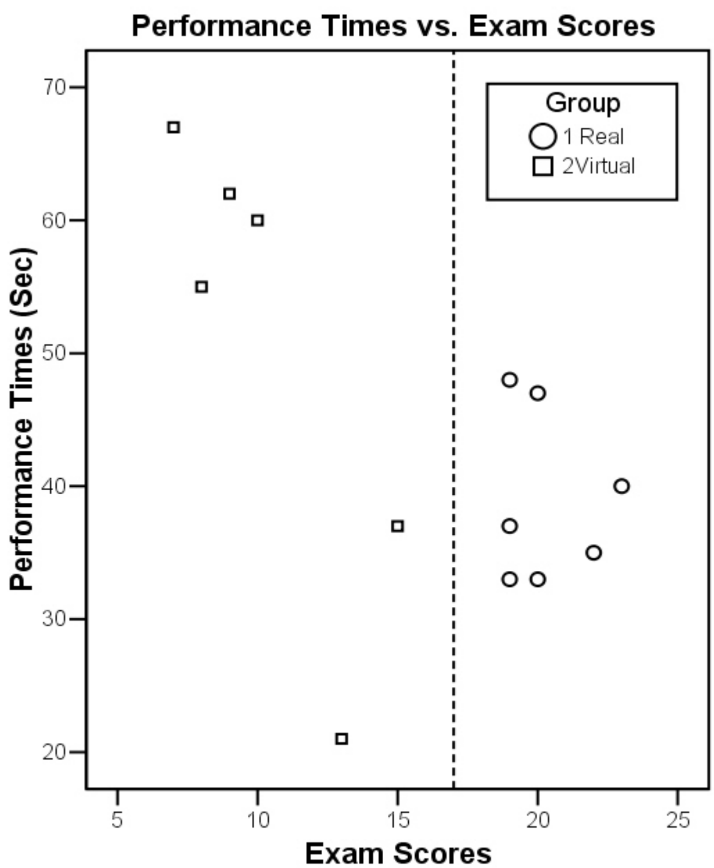

Figure 9. Scatter Plot Graph for Retrieval Times and Spatial Exam Scores

B. DISCUSSION

1. General Discussion

The general results of the experiment indicated that there was not a significant difference between group ability to acquire the requisite level of spatial orientation in

order to successfully retrieve the correct object from the real world environment; whether they were pre-exposed to the PC-based virtual environment or the real world environment. These results are congruent with much of the literature on using virtual environment technology to train real world spatial orientation with respect to landmark and route knowledge. The results for testing survey knowledge acquisition, however, did not match previous research results in this area. There are several contributing factors that may have attributed to the above result from the experiment.

The succeeding section discusses environment, participant, and transfer of training issues that are possible contributing factors which, if taken into account for future work, may produce stronger, more conclusive results.

a. Environment Issues

In order to train an individual to successfully navigate through a real environment they must posses an adequate level of landmark and route knowledge. This study showed that it was possible to transfer that knowledge to an individual using a PC-based virtual representation of the environment. However, the data also indicated that participants in the virtual group did not acquire spatial knowledge at the same level as those participants pre-exposed to the real world environment. This maybe due in part to a fidelity issue associated with the virtual model. Although virtual environment technology has vastly improved over the past several years, currently it is impossible to exactly replicate an environment to the point that there is absolutely no difference between the virtual and real world environments.

Fidelity issues in the virtual environment may have also played a role in the test group's ability to acquire the same level of survey knowledge that the control group acquired. The data in the experiment indicated that there was a significant difference between the two groups, with the real environment group doing on average fifty percent better than the virtual group.

b. Participants Issues

The experiment was conduct with a relatively small sample size of fourteen. Additionally, the extraction of the outlier in the virtual group for data analysis

reduced this number even more. A study of this type should include on the order of ten times as many participants in order to make stronger correlations between using a PC-based virtual environment to train spatial knowledge and environment familiarity.

As in previous studies as well as the experiment present here, population samples are restricted to a specific domain. This experiment randomly selected participants from a population of U.S. Navy enlisted personnel. Previous studies have used foreign and U.S. officers. Each of these population samples has varying degrees of experience relating to virtual or computed based training. In order to make stronger generalization of the efficacy of using PC-based or any other types of virtual training environments in the military, a broader sample of the military population at larger should be used.

c. Transfer of Training Issues

Positive training transfer is another important aspect that plays a critical role in the efficacy of this type of study. The participants' ability to properly transfer the spatial orientation they learned from exposure to the virtual environment may have been impeded by the shear novelty of such an environment. The virtual environment, for most of the participants, was a new device in which to view some aspect of the real world. The real world participants do not readily experience this novelty factor. In addition, participants using the virtual replication of the F-1 trainer did not experience a sense of immersion within the environment as those pre-exposed to the actual training environment had experienced.

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V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSIONS

1. General

The focus of this thesis was to conduct an experiment to determine the efficacy of using a PC-based virtual environment to aid participants in acquiring a requisite level of spatial orientation and environment familiarity in order to perform task at the same level participants pre-exposed to the real world environment. Previous studies in this area have been conducted using other virtual environment technologies, such as CAVES or HMDs, to evaluate performance in a real world environment. In addition, those studies have each used different approaches to measuring that performance. The approach taken in this study was to use a standard PC-based virtual environment configuration and evaluate performance in a real world environment using measure that translate well to real world task accomplishment.

The results from the experiment were analyzed in order to determine if there was a correlation between using the PC-based virtual environment and performing in the real world environment. The following conclusions stand to illustrate the efficacy of such an environment.

a. Participants pre-exposed to the PC-based virtual environment acquired the same spatial orientation and familiarity, with respect to their landmark and route knowledge, as those participants pre-exposed to real world environment, however not at the same level.

b. Participants pre-exposed to the PC-based virtual environment did not acquire the same spatial orientation and familiarity, with respect to their survey knowledge, as those participants pre-exposed to the real world environment.

c. Participants pre-exposed to the PC-based virtual environment performed at or near the same level after subsequent exposure to the real world environment.

B. RECOMMENDATIONS

1. Different Media

While this study only looked at using a PC-based virtual environment configuration, the use of other media delivery methods, e.g., video or still picture images, should be explored. The use of other delivery methods may reveal that training in spatial environments, critical to the transfer of training to computer based methods, can be done in methods other than virtual environments

2. Sample Size

This study suggest that there is evidence that using a PC-based virtual environment is as good as the real world environment when training individuals in acquiring spatial orientation and familiarity in a new environment. However, in order to state that stronger and more conclusively, future studies of this type should be conducted using a more congruent and larger sample of the general military population.

APPENDIX A. EXPERIMENT OUTLINE

1) In Brief /Consent Form/Pre-Survey

a) Time – 5 Min.

b) Location-Firefighting Training School San Diego, CA.

c) Monitor – LT. Matthew Molmer

d) Materials – IRB Consent, Privacy Act, & Minimal Risk Form, Pencil, Introduction Briefing Scripts, Pre-Survey

2) PC Interface Familiarization (Virtual Environment Group Only)

a) Time – 5 Min.

b) Location- Firefighting Training School San Diego, CA.

c) Monitor – LT Matthew Molmer

d) Materials – Alienware Desktop Computer System, Mouse, Keyboard, Virtual Environment Group Briefing Script

3) Guide Tour Using PC-based Virtual Environment

a) Time – 3 – 5 minutes each Participant

b) Location- Classroom Firefighting Training School San Diego, CA.

c) Monitor – LT Matthew Molmer

d) Materials – Alienware Desktop Computer, Mouse, Keyboard, Virtual Environment Group Briefing Script

e) Tour through Virtual Spaces:

(1) Space 1: Deep Fat Fryer Space - Includes Power Panels, Gaylord Hood & Activation Bottle, Storage Space Entrance.

(2) Space 2: Boiler Space: Includes Auxiliary Boiler, Fuel Oil Trip Value, Power Panels, Battle Lantern, Halon Bottles and Actuator.

(3) Space 3: Shaft Alley: Includes Shaft, AFFF Hose Reel, Power Panel.

(4) Space 4: Laundry Space: Includes Dryer, Table, Power Panel.

4) Guided Tour in Real World

a) Time – 5 minutes per space for each participant

b) Location- F-1 Firefighting Trainer School San Diego, CA.

c) Monitor – LT Matthew Molmer

d) Materials – F-1 Firefighting Trainer, Real World Group Briefing Script

e) Tour through Real Environment:

(1) Space 1: Deep Fat Fryer Space - Includes Power Panels, Gaylord Hood & Activation Bottle, Storage Space Entrance.

(2) Space 2: Boiler Space: Includes Auxiliary Boiler, Fuel Oil Trip Value, Power Panels, Battle Lantern, Halon Bottles and Actuator.

(3) Space 3: Shaft Alley: Includes Shaft, AFFF Hose Reel, Power Panel.

(4) Space 4: Laundry Space: Includes Dryer, Table, Power Panel.

5) Administer spatial exam

a) Time – 15 minutes for each participant

b) Location- Classroom Firefighting Trainer School San Diego, CA.

c) Monitor – LT Matthew Molmer

d) Materials – Spatial exam, pencils, stop watch

6) Evaluation and Test Using Real Environment

a) Time – 10 – 15 minutes each Participant

b) Location- F-1 Firefighting Trainer School San Diego, CA.

c) Monitor – LT Matthew Molmer

d) Materials – F-1 Firefighting Trainer, Testing and Evaluation Briefing Script, five different colored flags

e) Testing and Evaluation Using Real Environment:

Read Testing briefing sheet to participants and conduct test.

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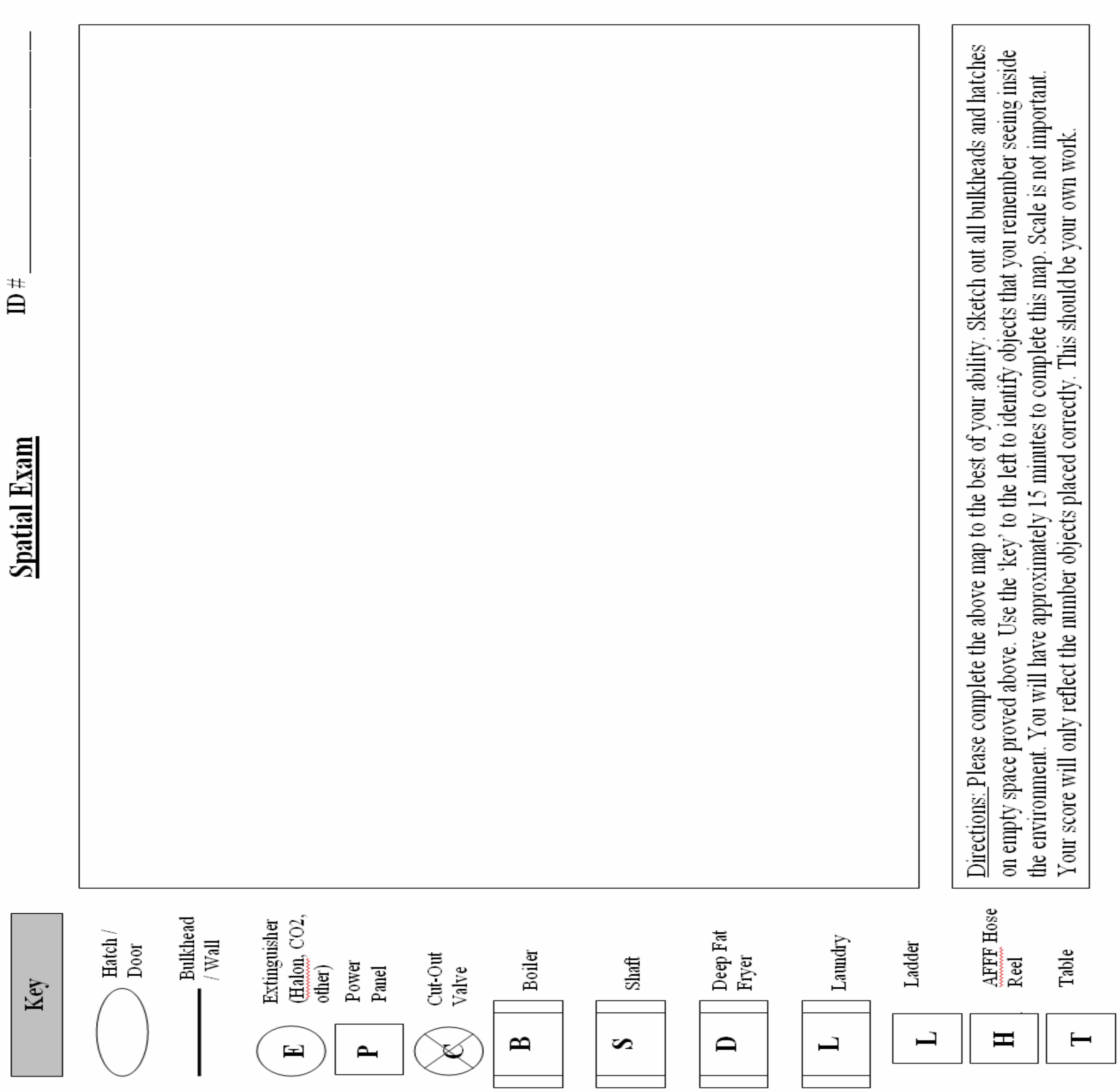
APPENDIX B. SPATIAL EXAM FORM



Spatial Exam

ID # ____________

Key

(oval)	Hatch / Door
(line)	Bulkhead / Wall
E	Extinguisher (Halon, CO2, other)
P	Power Panel
C	Cut-Out Valve
B	Boiler
S	Shaft
D	Deep Fat Fryer
L	Laundry
L	Ladder
H	AFFF Hose Reel
T	Table

Directions: Please complete the above map to the best of your ability. Sketch out all bulkheads and hatches on empty space proved above. Use the 'key' to the left to identify objects that you remember seeing inside the environment. You will have approximately 15 minutes to complete this map. Scale is not important. Your score will only reflect the number objects placed correctly. This should be your own work.

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APPENDIX C. RETRIEVAL TASK LIST

Task 1: Retrieve Red Flag from Galley

Location: Deep-Fat Fryer

Task 2: Retrieve Blue Flag from Laundry Room

Location: Steam Cutout Valve

Task 3: Retrieve Yellow Flag from Shaft Alley

Location: Exposed Shaft

Task 4: Retrieve Green Flag from Boiler Space

Location: Fuel Cutout Valve

Task 5: Retrieve Purple Flag from Shaft Alley

Location: AFFF Hose Reel

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APPENDIX D. BRIEFING SCRIPTS

<u>Introduction Briefing Script (All Groups)</u>

Good Afternoon and welcome to the Navy's Firefighting School. My name is LT Matthew Molmer and this is DC1 Potter. I am a student at the Naval Post Graduate School in Monterey, CA. I am conducting a study to determine if using a PC-based virtual environment can assist personnel become familiar with a new or unfamiliar real small-scale real environment. Without any prior knowledge of the actual layout of a real environment can personnel become spatially orientate to a real space by first viewing it as a 3-D model on a PC.

This study does not test your ability to perform in a real or virtual environment, but only how a virtual model can be used to assist personnel become familiar with an actual environment. The data collect from this study maybe used by the Navy to assist in building future PC-based gaming software to enhance training in the fleet. You will not be performing any actual firefighting during this study.

For this study you will be randomly assigned to 1 of 2 groups: a Real Environment Group or a Virtual Environment Group. Each of you will be asked to fill out a brief pre-survey to gather some basic demographic information and general work experience. Each group will be given a guided tour through their assigned environments. After completion of the guided tour, each of you will be asked to sketch or map out the layout of the environment in which you toured to the best of your recollection. The sketch paper will be provided to you. When all personnel have completed their sketch, your group will assemble in front of the F-1 trainer for further instruction on completing a retrieval task inside the real environment. This study should take no more than 2 hours per group to complete. Upon completion of each phase of this study, you will be given a short debriefing.

If you have any questions, at anytime, throughout any phase of the study, please don't hesitate to ask.

(HAND OUT CONSENT FORMS)

Please read and sign the consent form.

(HAND OUT SURVEY FORMS)

Please complete the pre-survey. As outlined in the consent form, your answers will be held strictly confidential and will only be used in conducting this study. Please be sure to write your ID number in the top right hand corner of your survey form.

(PASS AROUND RANDOM NUMBER ASSIGNMENT BIN)

Please take a number. This will be your group assignment for reminder of this study. Please write that number in the top right-hand corner of your survey form. Group 1 is designated as the Real Environment Group. Group 2 is designated as the Virtual Environment Group.

(COLLECT ALL FORMS)

(DISMISS VE GROUP TO RECONVENE)

VE Group, please assemble back in this classroom in 1 hour.

(ASSEMBLE REAL ENVIRONMENT GROUP IN FRONT OF F-1 TRAINER)

Guided Tour (All Groups)

During the guided tour of the F-1 trainer you will explore the spaces on the first floor of the F-1 trainer. In each space your attention will be directed to specific aspects and equipment within that space. Your time in each space will be approximately 5 minutes. You will not be able to take written notes or draw sketches of the spaces.

After your exploration of the all the spaces is completed, your group will reconvene in the classroom and each of you will be instructed to recreate the spatial layout with a written sketch on a form that I will provide to you.

You may ask safety and technical questions anytime during the guided tour phase of the study. You are asked not to ask question relating to the spatial layout of the spaces.

Experiment Briefing (All Groups)

(MEET PARTICIPANTS IN FRONT OF F-1 TRAINER)

You will be performing two randomly selected retrieval tasks in the F-1 trainer. Each task consists of retrieving a specific colored flag from one of the spaces you explored during the guided tour phase. I will give you the specific flag color, the space, and location of the flag. Your instructions are to retrieve the flag as quickly as possible and you time will be recorded. Your group will be brought to the starting point from the 2^{nd} deck so you do not traverse through the 1^{st} deck testing area. I ask that you not run during your time in the trainer. You may proceed however at a hurried pace to retrieve your flag. After you have retrieved your 2^{nd} flag, please wait off to the side until your entire group has finished their task and you will all exit the F-1 trainer together.

(WALK GROUP UP TO 2^{nd} DECK AND DOWN TO STARTING POINT ON 1^{st} DECK)

(GROUP RETRIEVAL TASK INSTRUCTIONS)

Task 1: Retrieve Red Flag from Galley

Location: Deep-Fat Fryer

Task 2: Retrieve Blue Flag from Laundry Room

Location: Steam Cutout Valve

Task 3: Retrieve Yellow Flag from Shaft Alley

Location: Exposed Shaft

Task 4: Retrieve Green Flag from Boiler Space

Location: Fuel Cutout Valve

Task 5: Retrieve Purple Flag from Shaft Alley

Location: AFFF Hose Reel

APPENDIX E. PARTICIPANT CONSENT FORM

Naval Postgraduate School

Participant Consent Form &
Minimal Risk Statement

Introduction. You are invited to participate in a study entitled Spatial Orientation in small scale Virtual Environments being conducted by the Naval Postgraduate School MOVES Institute.

Procedures. If I agree to participate in this study, I understand I will be provided with an explanation of the purposes of the research, a description of the procedures to be used, identification of any experimental procedures, and the expected duration of my participation. *Synopsis*: There will be three phases of the experiment: (1) a 30 minute environment familiarization phase (2) an execution phase lasting approximately 1 hour, during which you will be expected to accomplish a number of tasks related to navigating in a real building environment (3) and an evaluation phase, during which you will expected to take a short written exam.

Risks and Benefits. I understand that this project does not involve greater than minimal risk and involves no known reasonably foreseeable risks or hazards greater than those encountered in everyday life. I have also been informed of any benefits to myself or to others that may reasonably be expected as a result of this research.

Compensation. I understand that no tangible reward will be given. I understand that a copy of the research results will be available at the conclusion of the experiment.

Confidentiality & Privacy Act. I understand that all records of this study will be kept confidential and that my privacy will be safeguarded. No information will be publicly accessible which could identify me as a participant, and I will be identified only as a code number on all research forms. I understand that records of my participation will be maintained by NPS for five years, after which they will be destroyed.

Voluntary Nature of the Study. I understand that my participation is strictly voluntary, and if I agree to participate, I am free to withdraw at any time without prejudice.

Points of Contact. I understand that if I have any questions or comments regarding this project upon the completion of my participation, I should contact the Principal Investigator, Perry McDowell, 656-7591, mcdowell@nps.edu. Any medical questions should be addressed to LTC Eric Morgan, MC, USA, (CO, POM Medical Clinic), (831) 242-7550, eric.morgan@nw.amedd.army.mil.

Statement of Consent. I have read and understand the above information. I have asked all questions and have had my questions answered. I agree to participate in this study. I will be provided with a copy of this form for my records.

Participant's Signature　　　　　　　　　　Date

Researcher's Signature　　　　　　　　　　Date

APPENDIX F. PARTICIPANT SURVEY

Participant Demographics, Experience, and Training Questionnaire
Spatial Orientation in Small Scale Virtual Environments
Sponsored by the MOVES Institute, Naval Postgraduate School

Subject # ____________________
(Your subject number is the first three letters of your last name and last 4 digits of your SSN. For example: FC3 Joe Sailor, 123-45-6789 is "SAI6789")

Multiple Choice questions: Place a check in circle , for example: YES O NO ✓
Fill-in questions, use space provided (Enter "N/A" if not applicable): Firefighting Trainer

Demographics

	Male	Female		
1 Gender:	O	O		
2 Height:	______ft	______in		
	Right	Left	Ambidextrous	
3 Preferred hand for using a computer mouse:	O	O	O	
4 Age:	_____yrs			
5 Years of Military Service:	_____yrs			
6 Current Command:	____________________			(USS NEVERSAIL DDG-79)
7 Pay Grade:	____________________			(i.e. E-5)
8 Rate:	____________________			(i.e. FC1)
9 NEC (if known):	____________________			(i.e. 1127)
	Active	USNR		
10 Current Service Component:	O	O		

Experience

	Yes	No		
11 Have you ever used one of the Navy's Firefighting Trainers?:	O	O	If "No", proceed to #12.	
11a. If "Yes", where was the trainer located?:	____________________		(i.e. San Diego, Norfolk, etc.)	
11b. Approx. how long ago did you use the trainer?:	____________________		(i.e. Week, Month, etc.)	
	Yes	No		
12 Are you (or have you ever been) assigned to a DC team at your command?:	O	O	If "No", proceed to #13.	
12a. If "Yes", which DC team are (were) you assigned?:	____________________		(i.e. locker, hose team, etc.)	
12b. What position on the team did you hold:	____________________		(i.e. nozzleman, etc.)	
	< 2 months	2-6 months	7-12 months	> one year
13 How long have you been with your current command?:	O	O	O	O
	Yes	No		
14 Have you participated in firefighting training at your current command?:	O	O	If "No", proceed to #15	
	1 to 3	4 to 7	8 or more	
14a. If "Yes", how many times per month do you participate in training?:	O	O	O	
	Yes	No		
15 Did you ever experience a sense of being spatial lost inside a building or ship?	O	O		
	< 1 week	1-3weeks	1 month	> one month
16 Approx. how long did it take you to fell comfortable finding your way around your previous or current command ?:	O	O	O	O

Page 1 of 2

Simulations Experience

	Daily	Weekly	Monthly	Never	
17 In the past two years, how often did you play video games?:	O	O	O	O	
	Daily	Weekly	Monthly	Never	
18 How often do you *now* play video games?:	O	O	O	O	

For Questions 19, 20, and 21, mark all answers that apply.

	First Person Shooter	Sports	Strategy	Fantasy	None
19 What types of video games do / did you play?:	O	O	O	O	O
19a. If you played First Person Shooter games, list the two most recent ____________					
	PC / Mac	X-Box	PS2	Other	N/A
20 If you play games,what platform do you prefer?:	O	O	O	O	O
	Keyboard/Mouse	Joystick	Gamepad	Other	N/A
21 If you play PC / Mac games, what controls do you use?:	O	O	O	O	O

General Questions

	Poor	Fair	Averge	Good	Excellent
22 Rate your current health?:	O	O	O	O	O
	Yes	No			
23 Have you ever become nauseous or motion sick while playing a video game?:	O	O	If "No", proceed to #24		
	Once	Rarely	Seldom	Occasionally	Frequently
23a. How often have you experienced this?:	O	O	O	O	O
24 Thank you for your participation.					

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   Monterey, CA

5. Matthew Molmer
   Naval Postgraduate School
   Monterey, CA